

Tropical Cyclone Report  
Tropical Storm Grace  
30 August - 2 September 2003

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Tropical Storm Grace was a short-lived tropical cyclone that developed over the western Gulf of Mexico. Grace moved inland along the upper Texas coast and produced little damage.

a. Synoptic History

A strong tropical wave, accompanied by a vigorous low pressure system, moved off the west coast of Africa on 19 August. Both conventional satellite data and QuikSCAT microwave wind data indicated that the wave came close several times over the next few days to developing into a tropical cyclone. Convection became most pronounced on 21 August when some outer banding features and a circular cirrus outflow pattern briefly developed. However, the rapid westward motion, exceeding 20 kt at times, may have disrupted the low-level circulation enough to prevent the convection from becoming concentrated near the center. The system also moved through a mid- to upper-level region of very dry air over the central tropical Atlantic, and by late on 22 August nearly all of the convection had dissipated.

As the pre-Grace wave continued its westward trek, a second convective development phase occurred when the system slowed as it moved across the Lesser Antilles on 24-25 August. However, southwesterly upper-level shear ahead of a large upper-level trough located to the west disrupted the development process. Devoid of significant convection, the wave moved west-northwestward at 6-8 kt until it reached the northwestern Caribbean Sea on 28 August, when deep convection re-developed along the wave axis. When the tropical wave crossed the northern Yucatan Peninsula on 29 August, a broad low pressure area re-developed along the wave axis as it turned northwestward toward the Texas coast. While there was an abundance of deep convection associated with this system, the disturbance remained poorly organized until later that day when satellite classifications were initiated by the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB).

Convective organization continued to improve during the early morning hours of 30 August, and surface observations in conjunction with satellite intensity estimates indicated that tropical Depression Eleven had formed about 290 n mi east-southeast of Corpus Christi, Texas. The "best track" chart of the tropical cyclone's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1.

The depression initially showed some signs of interaction with an upper-level cold low, but this was short-lived and subsequent reconnaissance flights indicated that the cyclone was mostly tropical in nature. More specifically, a reconnaissance flight at 2125 UTC 30 August indicated the depression had likely strengthened into Tropical Storm Grace around 1800 UTC about 245 n mi east-southeast of Corpus Christi, Texas. The upper-low situated a few hundred miles to the west of Grace

was forecast by most of the various numerical models to move quickly westward. However, this did not occur and, as a result, persistent southerly to southwesterly upper-level shear prevented the deep convection from organizing around the low-level circulation. While remaining broad and somewhat disorganized, Grace moved northwestward on 31 August at a faster forward speed of about 15 kt.

Due to the broad low-level inner wind field, it was difficult to pinpoint the exact location of Grace in satellite imagery and by reconnaissance aircraft. In addition, a large surface high pressure system located over the southeastern United States was strengthened the pressure gradient and the low-level wind field for several hundred miles northeast of the center. Grace was forecast to move inland in the vicinity of Corpus Christi, Texas. However, the long fetch of strong southeasterly winds and cyclonic shear, in conjunction with several bursts of deep convection east of the original low-level center, may have caused the spin up of a new center about 100 n mi farther to the north. This new circulation center of Grace moved inland near San Luis Pass, Texas on the southwestern tip of Galveston Island at 1100 UTC 31 August 2003 with 35-kt winds. The original circulation weakened and eventually dissipated before it made landfall. Grace continued to move northwestward and quickly weakened back to a tropical depression shortly after making landfall. Tropical Depression Grace turned northward over northeastern Texas on 1 September and merged with a frontal zone near the Arkansas-Oklahoma border early on 2 September.

#### b. Meteorological Statistics

Observations in Tropical Storm Grace (Figs. 2 and 3) include satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB) and the U. S. Air Force Weather Agency (AFWA), as well as flight-level and dropwindsonde observations from flights of the 53<sup>rd</sup> Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command.

Two ships reported tropical storm force winds associated with Grace. Several oil drilling platforms also observed tropical storm force winds, but these measurements were made several hundred feet above the surface. The ship and oil platform reports of winds of tropical storm force associated with Grace are given in Table 2. Selected surface observations from land stations and data buoys are given in Table 3.

Grace's peak intensity of 35 kt was based on a blend of a reconnaissance 1500 ft flight-level spot wind report of 43 kt, which converts to a surface wind value of approximately 34 kt, and two sustained 35-kt wind reports from the Sabine Pass (Sea Rim State Park – SRST5), Texas C-MAN station at 1000 UTC and 1200 UTC 31 August 2003. The 35-kt surface wind reports at Sabine Pass were also used to support the 35 kt intensity at landfall.

Maximum storm surge values were generally around 1-2 ft along the upper Texas coast, primarily on Galveston Island, and produced minimal effects.

Rainfall totals across the Houston metropolitan area and the upper Texas coast were in the 3 to 5 in range with some isolated reports in excess of 9 in. Grace's relatively fast forward speed of 10-15 kt during and after landfall helped to minimize the heavy rainfall and flash flood threat typically associated with landfalling tropical cyclones.

No tornadoes were reported.

c. Casualty and Damage Statistics

The main effect associated with Tropical Storm Grace was isolated heavy rainfall and some inland freshwater floods across the upper Texas coastal area, north of where the center of Grace made landfall.

No deaths or casualties were reported in association with Grace. No monetary damage figures are available and insured losses did not meet the \$25 million threshold in order to be recorded by the American Insurance Services Group.

d. Forecast and Warning Critique

Average official track errors (with the number of cases in parentheses) for Grace were 108 (5), 158 (5), 223 (5), and 305 (4) n mi for the 12, 24, 36, and 48 h forecasts, respectively<sup>1</sup>. These errors are much greater than the average official track errors for the 10-yr period 1993-2002 of 45, 81, 116, and 150 (Table 4). The significance is minimized due to the number of cases being small. The primary reason for the large official forecast (OFCL) errors was the re-development of the low-level center much farther north, near Galveston Island, where Grace eventually made landfall (Fig. 4). The official forecast closely followed the consensus of the interpolated GFDL, UKMET, NOGAPS, and GFS/AVN (GFDI, UKMI, NGPI, and AVNI, known as GUNA) models, which also performed poorly, and kept Grace farther south near Corpus Christi. However, it is noteworthy to point out that the real-time operational global models, AVNO, NGPS, and UKM (used to generate the interpolated models), as well as the interpolated 10-member GFS/AVN ensemble model, performed very well and correctly forecast a more northward landfall, albeit in the Freeport-Matagorda area. In contrast, the operational GFDL model performed rather poorly by taking Grace inland over and south of Corpus Christi, which resulted in a significant degradation in the GUNA consensus forecasts. However, none of the NHC forecast models correctly predicted the landfall on Galveston Island.

Average official intensity errors were 5, 15, 5, and 3 kt for the 12, 24, 36, and 48 h forecasts, respectively. For comparison, the average official intensity errors over the 10-yr period 1993-2002 are 6, 10, 13, and 15 kt, respectively. The higher than average 24 h intensity error was due to some slight intensification expected before. Instead, significant vertical shear remained across the Grace throughout its lifetime while over water.

Table 5 lists the watches and warnings associated with Tropical Storm Grace.

Acknowledgments

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<sup>1</sup> All forecast verifications in this report include the depression stage of the cyclone. National Hurricane Center verifications presented in these reports prior to 2003 did not include the depression stage.

Some of the data in this report was furnished by National Weather Service Offices in Houston/Galveston and Corpus Christi, Texas.

Table 1. Best track for Tropical Storm Grace, 30 August - 2 September 2003.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
30 / 1200	24.3	92.4	1008	30	tropical depression
30 / 1800	24.9	93.3	1009	35	tropical storm
31 / 0000	25.8	94.3	1009	35	"
31 / 0600	27.2	94.9	1008	35	"
31 / 1200	29.4	95.2	1007	35	"
31 / 1800	30.1	95.6	1009	30	tropical depression
01 / 0000	30.9	96.4	1009	25	"
01 / 0600	31.9	96.6	1010	20	"
01 / 1200	32.6	96.5	1010	20	"
01 / 1800	33.6	95.7	1011	20	"
02 / 0000	34.1	95.0	1011	15	"
02 / 0600	34.6	94.5	1013	15	"
02 / 1200					merged with frontal zone
31 / 1100	29.0	95.1	1007	35	landfall near San Luis Pass, Texas
31 / 1200	29.4	95.2	1007	35	minimum pressure

Table 2. Selected ship and oil drilling platform reports with winds of at least 34 kt for Tropical Storm Grace, 30 August - 2 September 2003.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
31/0000	WZJC	27.6	91.8	130 / 36	1011.3
30/1500	SHIP	26.8	91.25	150 / 40 G 50	missing
Oil Platforms					
31/0246	KQT8 (400 ft)	27.9	92.75	150/45	1011.8
31/0345	KQT8 (400 ft)	27.9	92.75	150/35	1012.8
31/1744	KQT9 (400 ft)	27.8	90.65	180/37	1016.2
31/1749	KQT8 (400 ft)	27.9	92.75	160/34	1013.9

Table 3. Selected surface observations for Tropical Storm Grace, 30 August-2 September 2003.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)			
<b>Texas</b>								
Alice Airport (KALI)			31/2223		26			
Baffin Bay - TCOON	31/0000	1008.2	30/2200		30			
Baytown - Hartman Brdg								3.98
Cedar Bayou - SH 146								3.50
Clear Creek - 2 <sup>nd</sup> Outflow								5.40
Cleveland								4.62
Eagle Point	31/1200	1007.9						
East Matagorda Bay			31/1200		32			
Freeport								5.57
Galveston Airport (KGLS)	31/1116	1008.5	31/0803	28	35			3.72
Galveston Buoy 42035			31/1300	26	33			
Galveston Pleasure Pier	31/1200	1007.4	01/0900	26	33			
Galveston North Jetty	31/1154	1007.3						
Garwood (Colorado River)								3.40
Goodrich (W5QVK)								5.35
Goodrich School								4.25
Horsepen Ck-Bay Ar Blvd								4.57
Houston Arpt (KHOU)								4.98
Houston Cedar Bayou								2.84
Houston Clr Ck - FM 528								3.43
Houston Int'cntl (KIAH)								2.96
Huntsville ASOS (KUTS)								7.94
Jamaica Beach (JBHT2)	31/1230	1008.2						5.01
Jamaica Beach CO-OP								2.92
Kingsville NAS (KNQI)			01/0057		26			
League City (NWS)								7.13
Matagorda River Locks								9.00
McMullen Co. Airport			31/2124		26			
Mesquite Point TCOON			31/0400		36			
Nassau Bay - Clear Creek								5.90
New Caney								5.14
Onalaska								3.28
Onalaska (W5GRZ)								4.65

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)			
Orange TCOON			31/1300		38			
Pearland								6.47
Point Blank 6N								5.04
Port O'Connor			30/2000		26			
Seabrook (NASA Rd 1)								6.89
Sea Rim St. Park (SRST2)			31/1220	35				
Sea Rim St. Park (SRST2)			31/1450	35				
Sea Rim St. Park (SRST2)			31/1444		46			
West Bay (29.14N 95.15W)	31/1000 <sup>1</sup>	1007.7						

<sup>a</sup> Date/time is for sustained wind when both sustained and gust are listed.

<sup>b</sup> Except as noted, sustained wind averaging periods for C-MAN and land-based ASOS reports are 2 min; buoy averaging periods are 8 min.

<sup>c</sup> Storm surge is water height above normal astronomical tide level.

<sup>d</sup> Storm tide is water height above National Geodetic Vertical Datum (1929 mean sea level).

<sup>1</sup> Minimum pressure reported three times between 1000-1200 UTC 31 July 2003.

Table 4. Preliminary forecast evaluation (heterogeneous sample) for Tropical Storm Grace, 30 August-2 September 2003. Forecast errors (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in bold-face type. Verification includes the depression stage, but does not include the extratropical stage, if any.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
CLP5	118 ( 5)	200 ( 5)	265 ( 5)	323 ( 4)			
GFNI	174 ( 3)	251 ( 3)	390 ( 3)	519 ( 2)			
GFDI	152 ( 3)	206 ( 3)	332 ( 3)	459 ( 2)			
GFDL	125 ( 4)	179 ( 4)	271 ( 4)	412 ( 3)			
GFDN	118 ( 2)	221 ( 2)	330 ( 2)	474 ( 2)			
LBAR	108 ( 5)	165 ( 5)	<b>207 ( 5)</b>	<b>257 ( 4)</b>			
AVNI	135 ( 3)	186 ( 3)	290 ( 3)	385 ( 2)			
AVNO	<b>63 ( 5)</b>	<b>99 ( 5)</b>	<b>180 ( 5)</b>	312 ( 3)			
AEMI	<b>81 ( 2)</b>	<b>100 ( 2)</b>	<b>149 ( 2)</b>	<b>98 ( 1)</b>			
BAMD	122 ( 5)	210 ( 5)	296 ( 5)	387 ( 4)			
BAMM	121 ( 5)	214 ( 5)	300 ( 5)	380 ( 4)			
BAMS	117 ( 5)	208 ( 5)	289 ( 5)	376 ( 4)			
NGPI	131 ( 4)	185 ( 4)	275 ( 4)	343 ( 3)			
NGPS	<b>92 ( 5)</b>	132 ( 5)	<b>209 ( 5)</b>	364 ( 3)			
UKMI	128 ( 2)	148 ( 2)	<b>202 ( 2)</b>	<b>253 ( 1)</b>			
UKM	<b>88 ( 3)</b>	<b>92 ( 2)</b>	<b>156 ( 2)</b>	<b>165 ( 1)</b>			
A98E	119 ( 5)	207 ( 5)	254 ( 5)	333 ( 4)			
A9UK	111 ( 3)	182 ( 3)	<b>212 ( 3)</b>	<b>279 ( 2)</b>			
GUNS	142 ( 2)	194 ( 2)	302 ( 2)	392 ( 1)			
GUNA	137 ( 2)	193 ( 2)	301 ( 2)	389 ( 1)			
OFCL	108 ( 5)	158 ( 5)	223 ( 5)	305 ( 4)			
NHC Official (1993-2002 mean)	45 (2985)	81 (2726)	116 (2481)	150 (2230)			

Table 5. Watch and warning summary for Tropical Storm Grace, 30 August-2 September 2003.

Date/Time (UTC)	Action	Location
30 / 1500	Tropical Storm Warning Issued	High Island, TX to Corpus Christi, TX
31 / 1500	Tropical Storm Warning Discontinued	

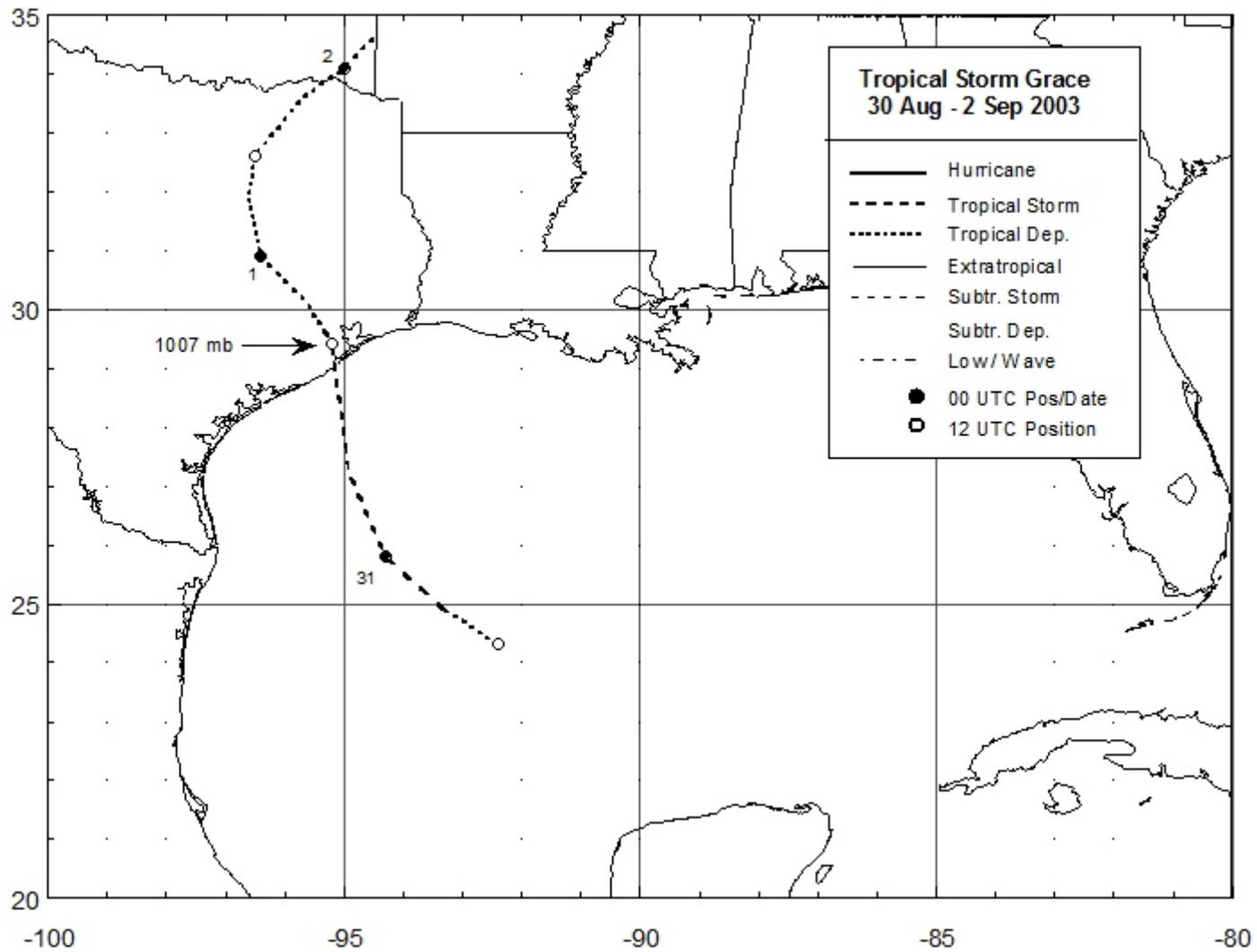


Figure 1. Best track positions for Tropical Storm Grace, 30 August-2 September 2003. Tropical depression positions inland are based on analyses from the NOAA Tropical Prediction Center/ National Hurricane Center and the Hydrometeorological Prediction Center (HPC).



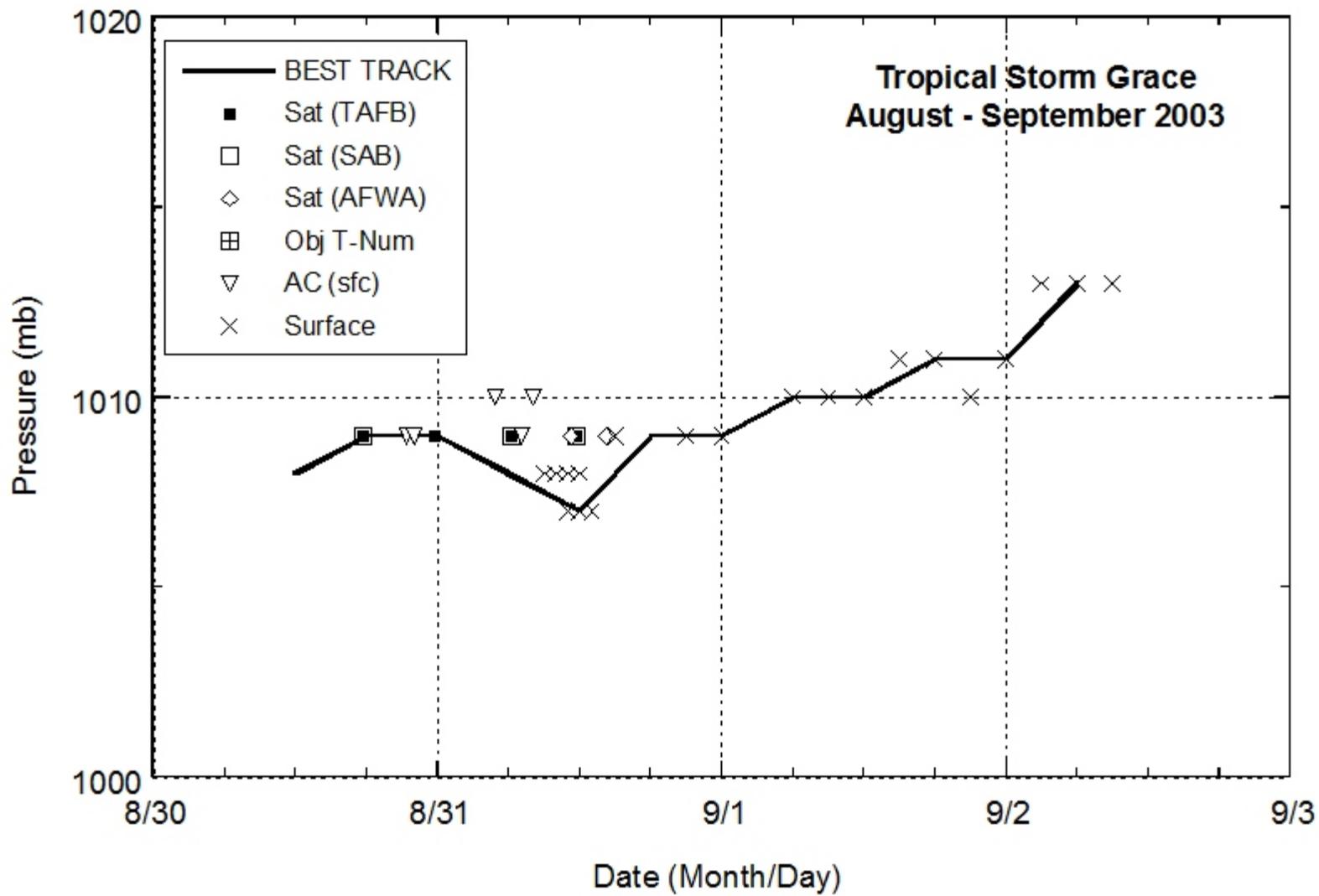


Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Grace, 30 August - 2 September 2003. Objective Estimates during the inland weakening stage are based on analyses from the NOAA Tropical Prediction Center/ National Hurricane Center and the Hydrometeorological Prediction Center (HPC).

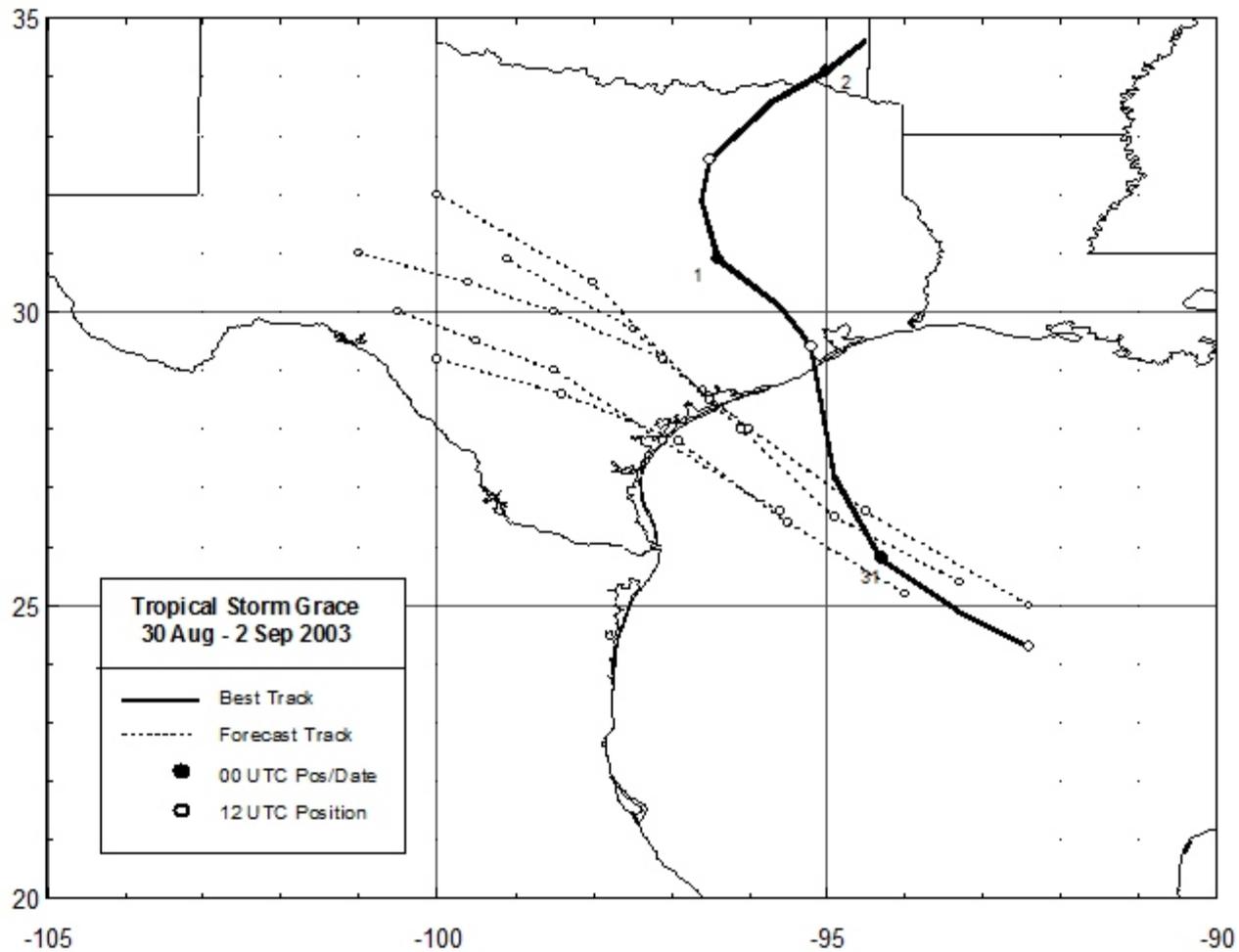


Figure 4. The five official track forecasts (dashed lines, with 0, 12, 24, 36, 48, and 72 h positions indicated) for Tropical Storm Grace, 30 August - 2 September 2003. The best track is given by the thick solid line with positions given at 6 h intervals. The poorly-defined low-level center, including its redevelopment farther north, led to unusually large track forecast errors.

